Forest Health Protection

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Western Hemlock Defoliation in North Idaho, Permanent Plot Results 2002-2007.

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INTRODUCTION

In 2002 aerial surveyors detected areas of defoliation in western hemlock (*Tsuga heterophylla*) on the Priest Lake and Sandpoint Ranger Districts of the Idaho Panhandle National Forest (IPNF) (Figure 1a). Late instar larvae and adults of budworms, *Choristoneura* species, were found in follow up ground surveys in the defoliated areas (taxonomic findings are summarized in Appendix A).

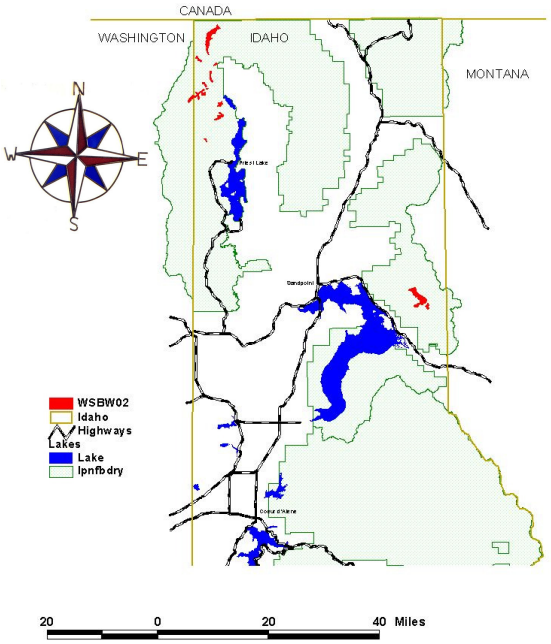
There has been one report from 1921-1922 of western spruce budworm feeding on western hemlock near Priest Lake, Idaho. There was no information on losses sustained as a result of the 1920's defoliation. Budworm defoliation was reported on the Coeur d'Alene River Ranger District in Steamboat and Cougar Creek in "minor" species (presumably western hemlock and grand fir) in 1924; in Steamboat, Cougar, and Grizzly Creek drainages in 1928; in Laverne Creek, Leiberg Creek, and Teepee Summit in 1929-33; and at the head of Cottonwood Creek in 1941 (Johnson and Denton 1975).

The recent defoliation presents an opportunity to investigate the potential impact of moderate to severe defoliation on western hemlock. Permanent plots were established in stands of western hemlock experiencing defoliation in 2002 and 2003. These plots were re measured annually through 2007. None of the permanent plot areas experienced significant defoliation in 2006 or 2007.

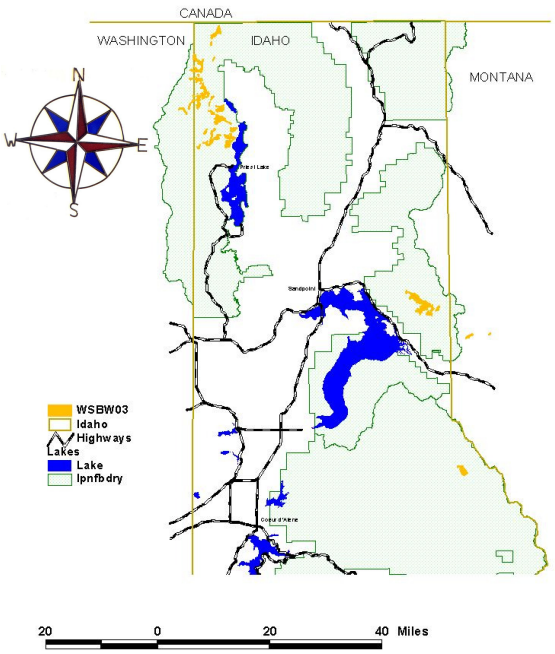
In 2004 budworm defoliation was observed in grand fir and Douglas-fir as well as western hemlock, but not in the permanent plots. Budworm defoliation is expected to continue into 2008. Budworm defoliation which started on the Sandpoint and Priest Lake Ranger Districts now extends southward into the Coeur d'Alene River Ranger District and eastward into western Montana (Figure 1, 2).

Figure 1: Budworm *(Choristoneura* spp.) defoliation mapped during aerial surveys in 2002-2007 in north Idaho. From 2002-2004 aerially detected defoliation in north Idaho was mostly noted in western hemlock, from 2005 through 2007 defoliation was also mapped in grand fir and Douglas-fir.

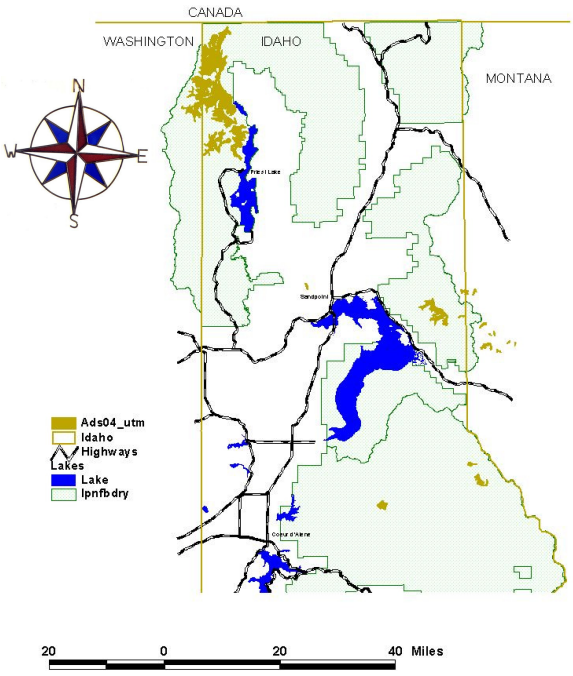
a) 2002 Defoliation



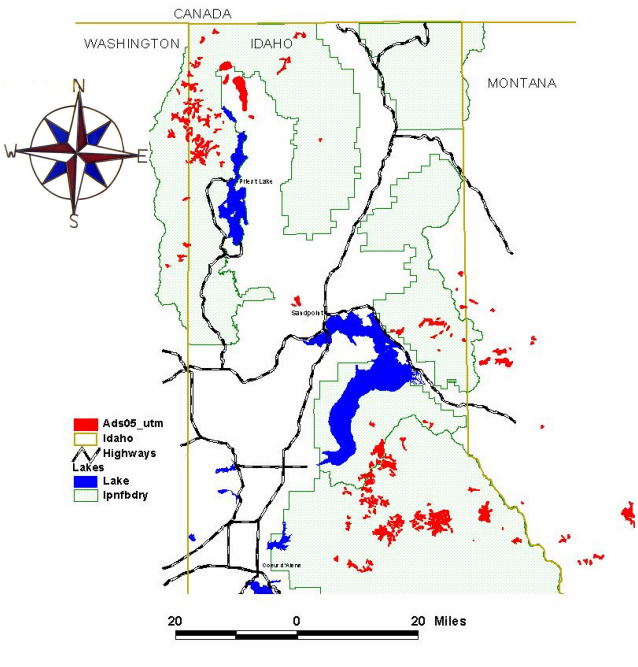
b) 2003 Defoliation



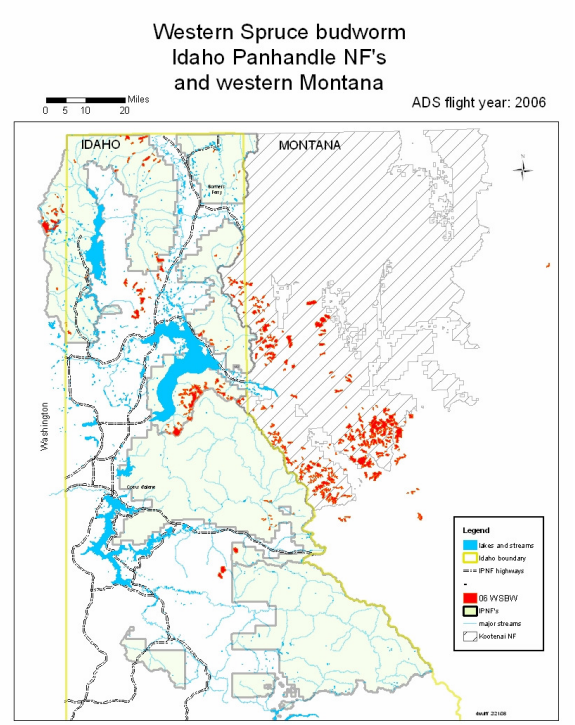
c) 2004 Defoliation



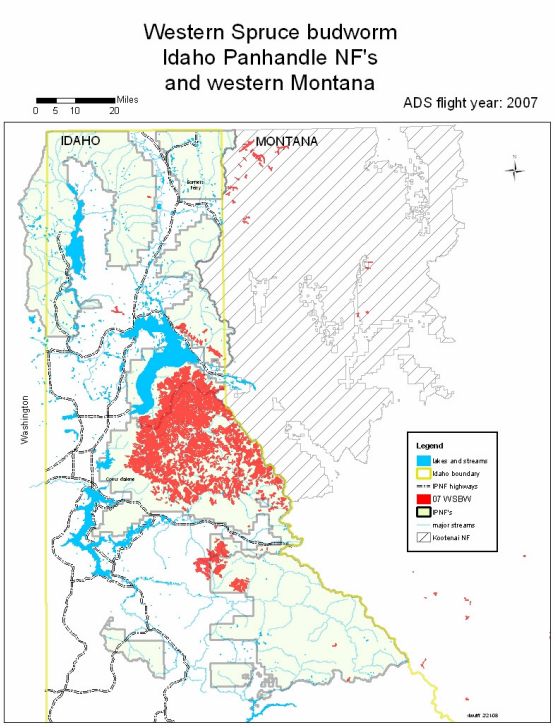
d) 2005 Defoliation



e) 2006* Defoliation

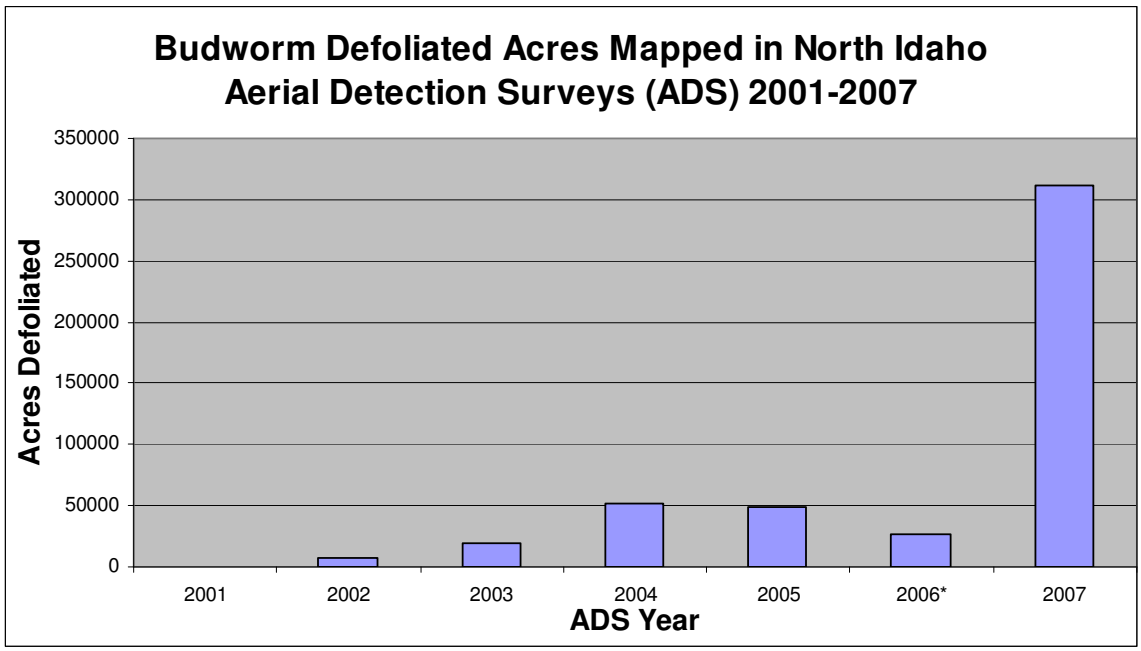


f) 2007 Defoliation



*Aerial surveys were not conducted over much of north Idaho in 2006 so this map under represents defoliation

Figure 2: Acres of budworm (*Choristoneura* spp.) defoliation mapped on the Coeur d'Alene River, Sandpoint, and Priest Lake Ranger Districts, Idaho Panhandle National Forest during aerial surveys in 2002-2007. From 2002-2004 defoliation was mostly mapped in western hemlock. From 2005 through 2007 defoliation was also mapped in grand fir and Douglas-fir.

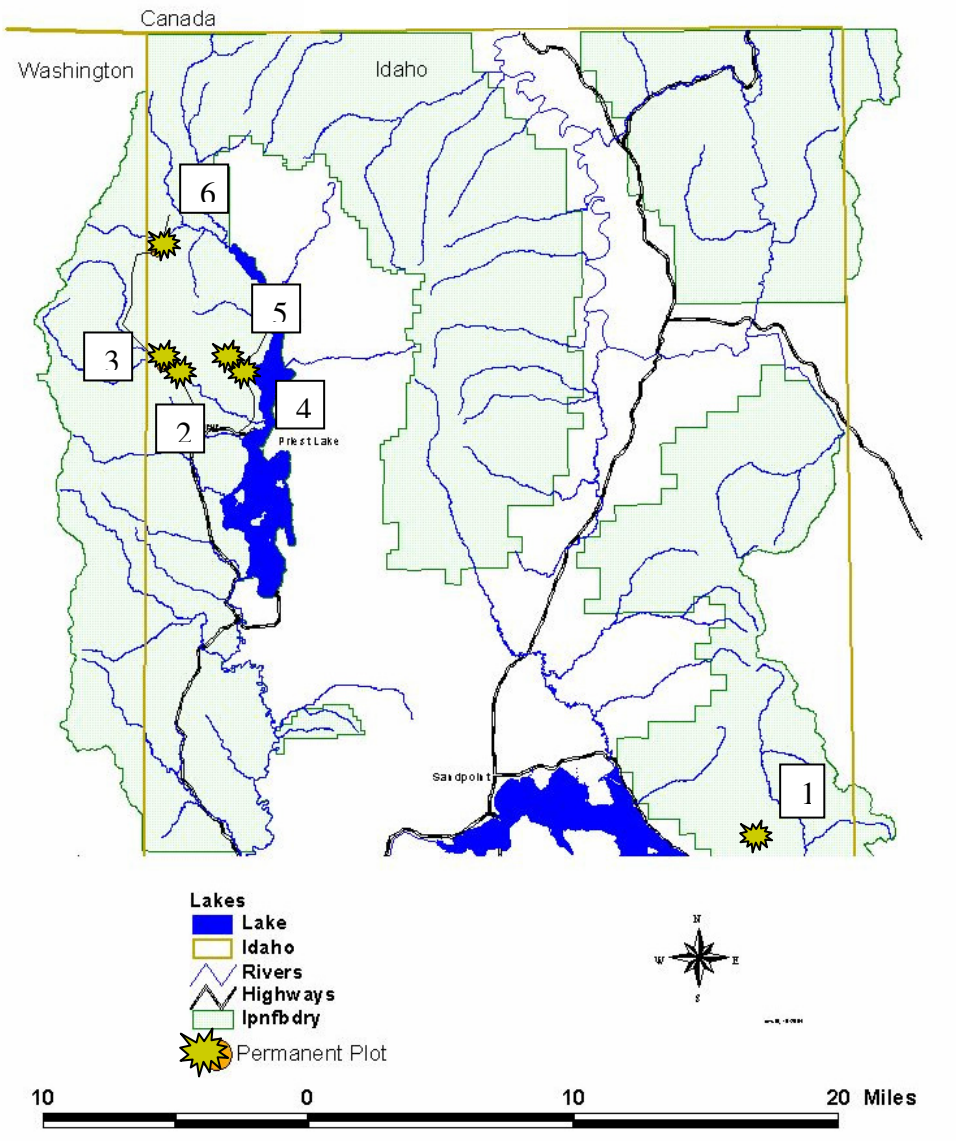


* Aerial surveys were not conducted over much of north Idaho in 2006 so this graph under represents defoliation for that year.

Permanent Plot Locations

Six western hemlock dominated defoliated areas were chosen and permanent plots were established to quantify defoliation of current year's foliage and tree damage in 2002 and 2003 (Figure 3).

Figure 3: Western hemlock defoliation permanent plot locations, Sandpoint and Priest Lake Ranger Districts, Idaho Panhandle National Forests. 1= Porcupine Creek (T29N, R2E, Sec 25 and T29N, R3E, Sec 30), 2= Granite Creek (T62N, R5W, Sec 33 and 34; T61N, R5W, Sec 3), 3= Athol Creek (T62N, R5W, Sec 29 and 32), 4= Distillery Bay (T62N, R4W, Sec 32), 5= Tango Creek (T62N, R4W, Sec 19 and 30), 6= South Fork of Gold Creek (T63N, R5W, Sec 20 and 29).



Permanent Plot Methods:

Five 1/20th acre fixed radius permanent plots were established along Porcupine Creek (T29N, R2E, Sec 25 and T29N, R3E, Sec 30) in the Lightening Creek drainage north of Clark Fork, Idaho in the fall of 2002. In the spring of 2003 five additional 1/20th acre plots were added along Porcupine Creek and ten 1/20th acre permanent plots were established in each of the following areas: Athol Creek (T62N, R5W, Sec 29 and 32), Granite Creek (T62N, R5W, Sec 33 and 34; T61N, R5W, Sec 3), Distillery Bay (T62N, R4W, Sec 32), Tango Creek (T62N, R4W, Sec 19 and 30), and South Fork of Gold Creek (T63N, R5W, Sec 20 and 29) (Figure 4, Appendix B).

On each plot all tree species 2 inches in diameter at breast height (DBH) and above were tagged and measured. Individual tree measurements included DBH, crown position (dominant (D), codominant (CD), intermediate (I), suppressed (S), regeneration (R)), and estimated percent defoliation of current year's foliage. A 1/100th acre fixed radius regeneration plot was established. In the regeneration plot seedlings and saplings (<2 inches DBH) were counted by species and rated for defoliation (Appendix C).

Defoliation rating were based on Twardus (1985) and involved visually dividing the tree crown into 1/3rds and assigning a defoliation code to each level (lower 1/3rd, middle 1/3rd, and upper 1/3rd):

Class	Percent Defoliation	Median Defoliation
1	0	No visible defoliation
2	1-25%	12.5%
3	26-50%	38%
4	51-75%	63%
5	76-99%	88%
6	100%	No current year foliage left

Crews were instructed to use binoculars and estimate defoliation on current year's foliage only.

Whole tree defoliation ratings were derived by adding the defoliation ratings for each crown 3rd and dividing by three.

Stand Conditions in Plot Areas:

Plot areas were selected based on the presence of visible western hemlock defoliation in 2002/ 2003. Western hemlock was the dominant overstory tree species in each of the 6 plot areas, though many also had western redcedar (*Thuja plicata*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmanii*), western larch (*Larix occidentalis*) and white pine (*Pinus monticola*) components (Table 1, Appendix C).

Table 1: Overstory stand composition for 6 western hemlock defoliation permanent plot areas 2003, Sandpoint and Priest Lake Ranger Districts, Idaho Panhandle National Forest.

Permanent Plot Area	Percent Stand Basal Area by Overstory Species							
	WH	WRC	GF	DF	WP	WL	SAF	Birch
Porcupine Creek	87	5	6	1	1	0	0	0
Granite Creek	76	24	0	0	0	0	0	0
Athol Creek	87	13	0	0	0	0	0	0
Distillery Bay	46	17	16	3	5	7	0	7
Tango Creek	78	18	4	0	0	0	0	0
S Fork Gold Creek	91	8	0	0	0	0	1	0

WH = western hemlock; WRC = western redcedar; GF = grand fir; DF = Douglas-fir; WP = white pine, WL = western larch, SAF = subalpine fir, Birch = birch.

In most of the plot areas, the regeneration was western hemlock dominated with minor components of other tree species (Table 2, Appendix C).

Table 2: Regeneration species composition for 6 western hemlock defoliation permanent Plot areas 2003, Sandpoint and Priest Lake Ranger Districts, Idaho Panhandle National Forest.

Permanent Plot Area	Trees per Acre by Species 0-4.9 DBH							
	WH	WRC	GF	DF	WP	ES	SAF	Junip.
Porcupine Creek	6510	390	0	60	60	60	30	420
Granite Creek	1830	540	0	0	0	0	0	0
Athol Creek	2910	270	60	30	0	0	0	0
Distillery Bay*	2850	2070	300	0	90	0	0	7
Tango Creek	1170	1380	0	0	60	0	0	0
S. Fork Gold Creek	2700	300	0	0	0	60	150	0

*also western larch 30 TPA, birch 90 TPA
WH = western hemlock; WRC = western redcedar; GF = grand fir; DF = Douglas-fir; WP = white pine, ES = Engelmann spruce, SAF = subalpine fir, Junip. = juniper.

Defoliation and Damage Summary 2002-2007: Defoliation was observed on western hemlock, grand fir, Douglas fir, subalpine fir, and Engelmann spruce. When more than one species co-existed on a plot, western hemlock tended to be the most severely defoliated (Appendix C). Defoliation was concentrated in the top crown 1/3rd of plot trees, especially during the first year of visible defoliation. The severity of defoliation varied between trees within and between plots and plot areas. Defoliation had subsided in all plots by 2006 with no defoliation noted in 2007 (Table 3, Appendix C).

Very few trees experienced 100% defoliation of current year's needles (defoliation rating = 6) in any crown third 2002-2004, and no plot trees experienced more than 75% defoliation of current year's needles (defoliation rating 5) in any crown third after 2004 (Table 4; Appendix C).

In 2005 top kill and mortality was noted in all plots and increased through 2007 (Table 5, Appendix C). Top kill was generally less than 10 percent of the top crown 1/3rd (five to fifteen feet). Most of the dead plot trees were either in a suppressed or intermediate crown position (Table 6). Mortality may have been the result of suppression, not defoliation.

Table 3: 2002-2007 top 1/3rd (Top) and whole tree (WT) average defoliation ratings for overstory trees on six western hemlock defoliation plot areas, Sandpoint and Priest Lake Ranger Districts, Idaho Panhandle National Forests.

Plot Area	# Trees	2002		2003		2004		2005		2006		2007	
		Top	WT	Top	WT	Top	WT	Top	WT	Top	WT	Top	WT
Porcupine Creek*	52*/ 132	2.58	2.20	4.47	3.18	2.37	1.69	1.4	1.2	1	1	**	**
Granite Creek	117			2.59	1.98	3.21	2.72	2.3	2.08	1.1	1.04	1	1
Athol Creek	133			1.47	1.23	2.60	2.15	2.3	2.1	1.08	1.02	1	1
Distillery Bay	186			1.97	1.62	2.4	2.16	2.0	1.8	1.16	1.08	1	1
Tango Creek	53			4.81	3.92	4.36	3.91	2.2	1.9	1.19	1.11	1	1
South Fork Gold Creek	130			3.15	2.42	4.0	3.48	1.8	1.6	1	1	1	1

*In 2002 only 5 plots had been established along Porcupine Creek with a total of 52 trees.
**Road conditions prevented re measurement of Porcupine Creek Plots in 2007.

Table 4: Number of trees with a top 1/3rd defoliation rating of 5 (76-99% defoliation) or 6 (100% defoliation) from 2002-2007 for six western hemlock defoliation plot areas, Sandpoint and Priest Lake Ranger Districts, Idaho Panhandle National Forests.

Plot Area	# Trees	2002		2003		2004		2005		2006		2007	
		6	5	6	5	6	5	6	5	6	5	6	5
Porcupine Creek	52*/ 132	0	45	37	2	9	8	0	0	0	0	0	0
Granite Creek	117			5	9	0	20	0	0	0	0	0	0
Athol Creek	133			0	2	0	9	0	0	0	0	0	0
Distillery Bay	186			0	2	1	1	0	0	0	0	0	0
Tango Creek	53			12	25	4	24	0	0	0	0	0	0
South Fork Gold Creek	130			15	18	18	41	0	0	0	0	0	0

Table 5: Number of top killed/ dead plot trees for six western hemlock defoliation plot areas during remeasurements in 2005, 2006 and 2007, Sandpoint and Priest Lake Ranger Districts, Idaho Panhandle National Forests.

Plot Area	# Plot Trees	2005		2006		2007	
		Top Kill	Dead	Top Kill	Dead	Top Kill	Dead
Porcupine Creek	132	60 (45%)	0	59 (45%)	1 (<1%)	*	*
Granite Creek	117	31 (26%)	2 (2%)	31 (26%)	2 (2%)	25 (21%)	8 (7%)
Athol Creek	133	4 (3%)	2 (2%)	13 (10%)	3 (2%)	19 (14%)	4 (3%)
Distillery Bay	186	0	7 (4%)	1 (1%)	11 (6%)	0	15 (8%)
Tango Creek	53	11 (21%)	1 (2%)	13 (25%)	2 (4%)	16 (30%)	3 (6%)
South Fork Gold Creek	130	12 (9%)	0	15 (12%)	1 (1%)	39 (30%)	6 (5%)
TOTAL	**751**	**118 (16%)**	**12 (2%)**	**132 (18%)**	**20 (3%)**	**99 (13%)**	**36 (5%)**

Table 6: Number of top killed/ dead plot trees by crown class for six western hemlock defoliation plot areas during final measurement in 2007, Sandpoint and Priest Lake Ranger Districts, Idaho Panhandle National Forests.

Plot Area	# Plot Trees	# Top Killed Trees					# Dead Trees				
		D	CD	I	S	R	D	CD	I	S	R
Porcupine Creek*	132	12	20	23	5	0	0	0	0	1	0
Granite Creek	117	1	7	10	7	0	0	0	1	7	0
Athol Creek	133	1	14	2	2	0	0	0	0	4	0
Distillery Bay	186	0	0	0	0	0	0	1	5	9	0
Tango Creek	53	2	10	3	1	0	0	0	0	2	1
South Fork Gold Creek	130	0	8	18	13	0	0	2	1	3	2
TOTALS	**751**	**16**	**59**	**55**	**28**	**0**	**0**	**3**	**7**	**26**	**3**

* Final measurement on Porcupine Creek occurred in 2006.

Conclusion:

Visible defoliation occurred in the western hemlock permanent plot areas for 3-4 years before subsiding. Defoliation was observed on different tree species including grand fir, Douglas-fir, Engelmann spruce, and subalpine fir, but with one exception (Tango Creek) was heaviest on western hemlock. Defoliation peaked in two plot areas in 2003 (Porcupine Creek and Tango Creek) and on the remaining four plot areas in 2004 (Granite Creek, Athol Creek, Distillery Bay, and South Fork Gold Creek). At its height some plot areas averaged up to 75% defoliation of current year's foliage in the top crown 1/3rd and 50% defoliation of current year's foliage over the whole tree. Individual tree defoliation ratings varied considerably within plots and between plot areas. The biggest impact from defoliation appears to

be top kill which occurred on between 0 to 30% of the plot trees in some plot areas. Plot tree mortality was observed, but was mainly confined to trees in intermediate or suppressed crown positions and may have been a result of suppression, not defoliation.

Collections of larvae from defoliated areas indicate a complex of 4 or 5 *Choristoneura* species are responsible, though *Choristoneura occidentalis*, the western spruce budworm, was the most abundant. Lower crown sampling did not uncover any of the more frequently encountered western hemlock defoliators such as the western blackheaded budworm (*Acleris gloverana*), western hemlock looper (*Lambdina fiscellaria*), and western false hemlock looper (*Nepytia freemani*). Only a few individual sawflies (*Neodeprion* spp.) were observed during sampling, not enough to result in the level of defoliation observed.

Literature Cited:

Johnson, Philip C. and Robert E. Denton. 1975. Outbreaks of the Western Spruce Budworm in the American Northern Rocky Mountain Area from 1922 through 1971. USDA-FS-Tech. Rpt INT-20

Twardus, D.B. 1985. Surveys and sampling methods for population and damage assessment. In: Brookes, M.H., Bolbert, J.J.; Mitchell, R.G.; Stark, R.W., editors. Managing trees and stands susceptible to the western spruce budworm. Tech. Bull. 1695. Washington, D.C: U.S. Department of Agriculture, Forest Service; 27-40.

Appendix A: Taxonomic Information, Western Hemlock Defoliation North Idaho 2003-2004

2003

In 2003, 18 adult moths were collected in areas of western hemlock defoliation in north Idaho (Bonner and Boundary County) and 5 adult moths were collected in areas of western hemlock defoliation in western Montana (Lincoln County). All moths were sent to Frank W. Merickel, curator WF Barr Entomological Museum, University of Idaho. Mr. Merickel then forwarded the pinned moths onto a Tortricid specialist for definitive identification.

All of the 23 moths sent in for identification were Tortricids in the genus *Choristoneura*. There were four species found in 2003(Table 1).

Table 1: 2003 identification of *Choristoneura* species collected from areas of western hemlock defoliation in northern Idaho and western Montana.

Number	Genus species	Location
6	*Choristoneura orae*	Bonner Co, ID
12	*Choristoneura occidentalis*	5 in Bonner Co, ID; 4 in Lincoln Co, MT; 3 in Boundary Co, ID
1	*Choristoneura lambertiana*	1 in Bonner Co, ID
4	*Choristoneura retiniana*	1in Boundary Co, ID; 2 in Bonner Co, ID

2004

In 2004 personnel from the Priest Lake Ranger District collected a number of branch samples from defoliated trees. The branch samples were sent to Carol Randall, Forest Health Protection Entomologist in Coeur d'Alene. Carol removed larvae from each branch sample and reared the larvae on the host from which they had been collected. As the larvae began to pupate, Carol forwarded them to Frank Merickel, curator WF Barr Entomological Museum, University of Idaho, for specimen preparation and identification.

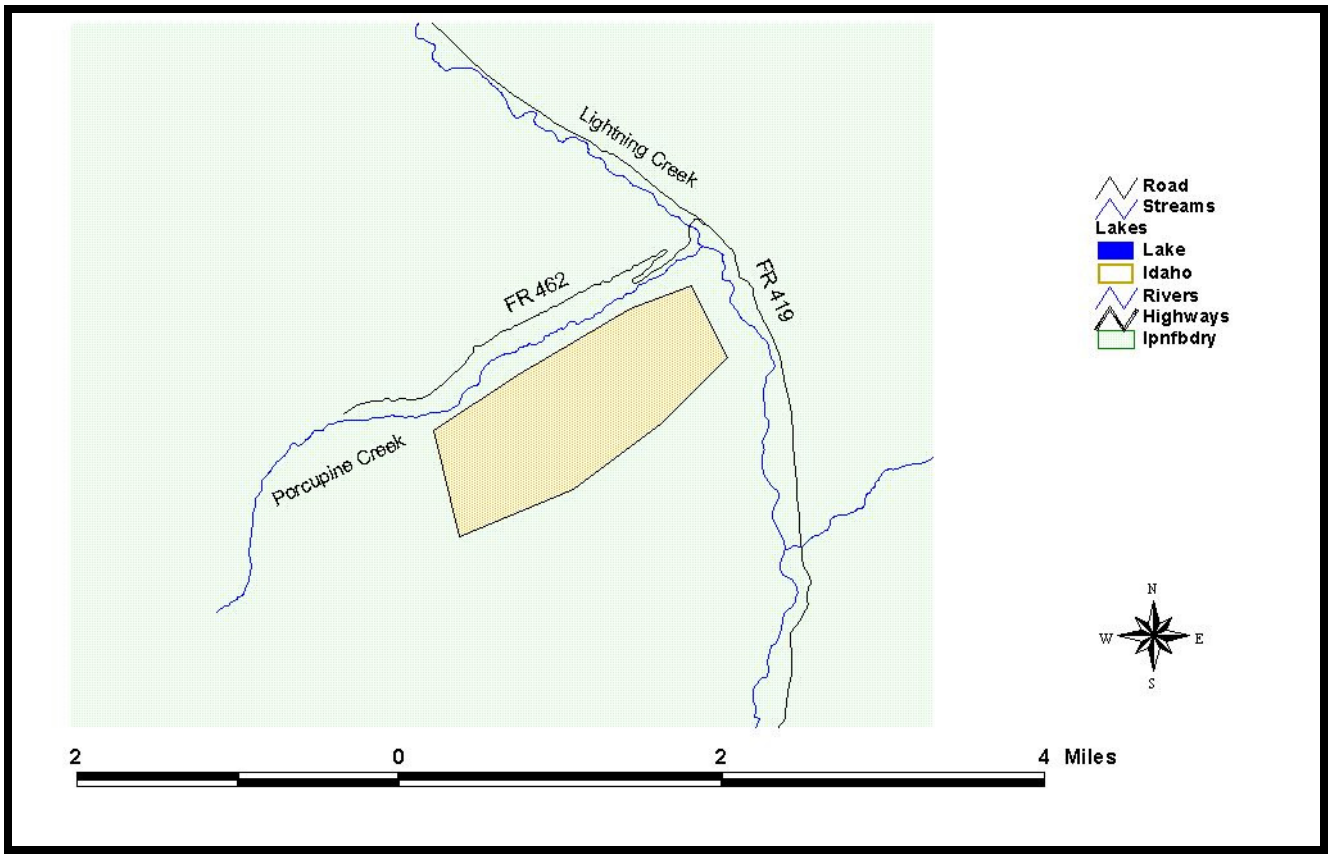
The 2004 host rearing resulted in 28 moths representing 5 *Choristoneura* species (Table 2) as determined by Ron Leuschner (Tortricid specialist in Manhattan Beach, CA). Mr. Merickel also reared out 8 Ichneumonid parasites.

Table 2: 2004 identification of *Choristoneura* species collected from areas of western hemlock defoliation in northern Idaho on the Priest Lake Ranger District, Idaho Panhandle National Forest.

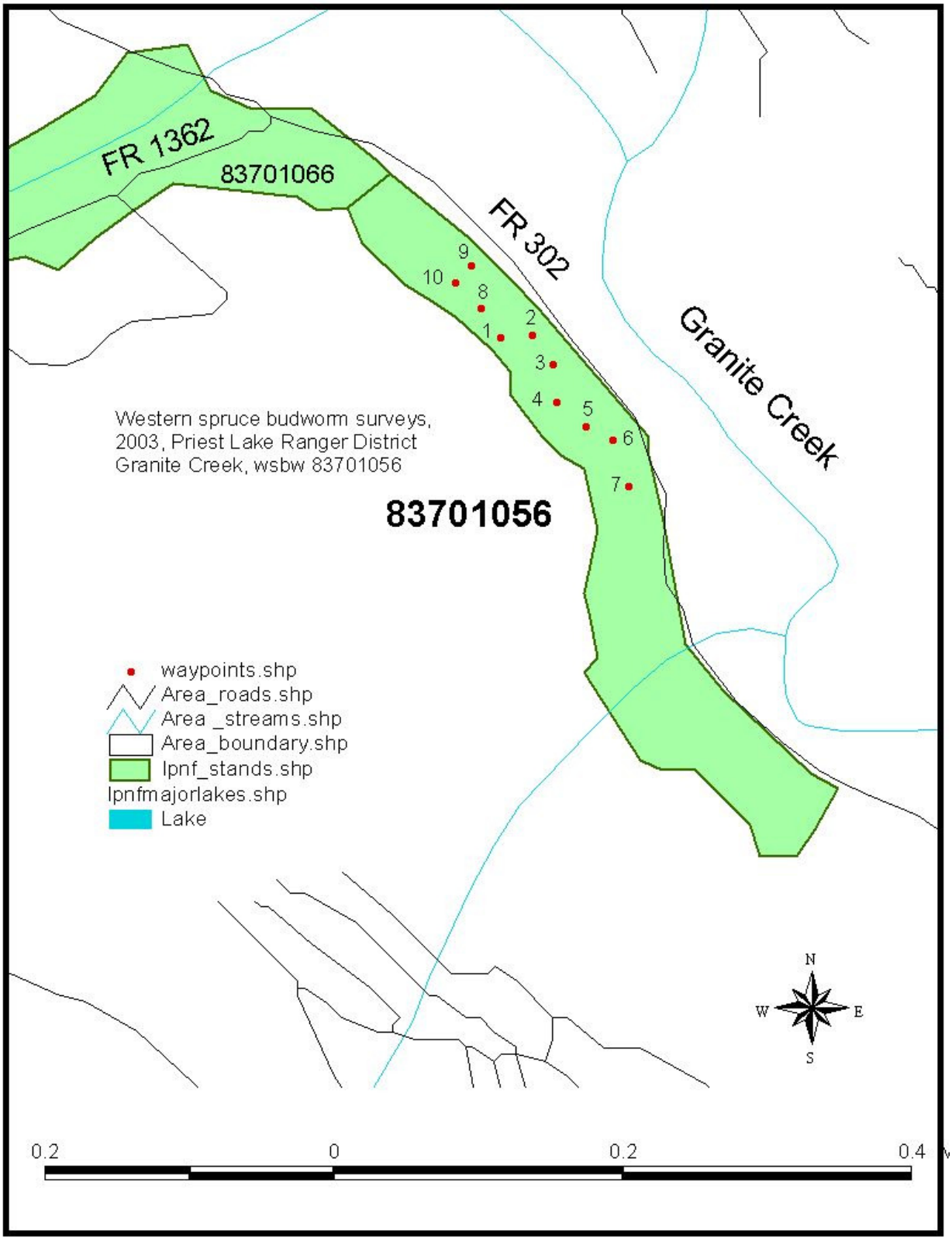
Number	Genus species
4	*Choristoneura orae*
18	*Choristoneura occidentalis*
1	*Choristoneura lambertiana*
2	*Choristoneura retiniana*
3	*Choristoneura fumiferana*

Appendix B: Permanent Plot Maps for Six Areas Monitoried for Western Hemlock Defoliation

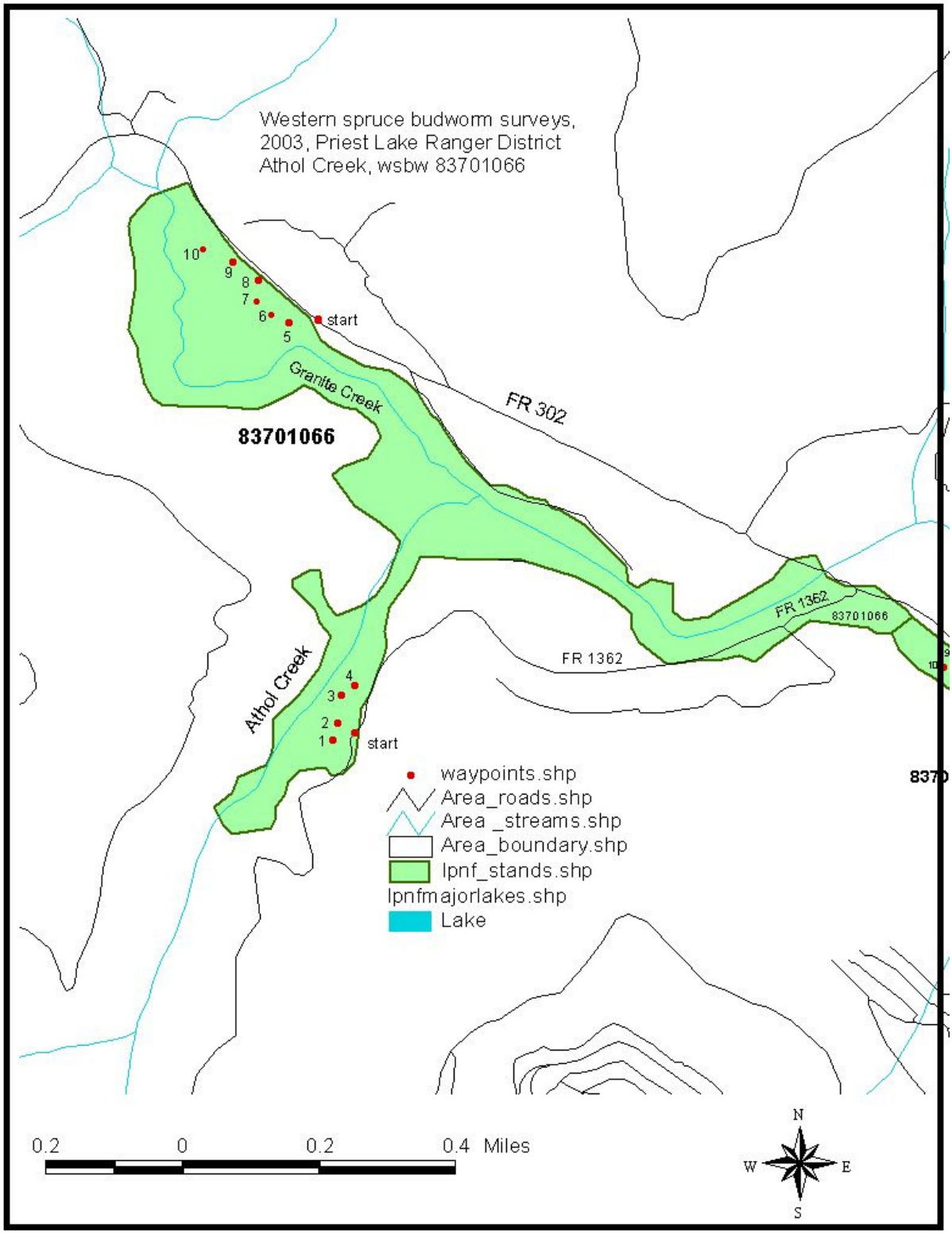
Area 1: Porcupine Creek western hemlock defoliation plots area on the Sandpoint Ranger District, IPNF (T29N, R2E, Sec 25 and T29N, R3E, Sec 30). Five plots were established fall 2002, 5 additional plots were established in 2003.



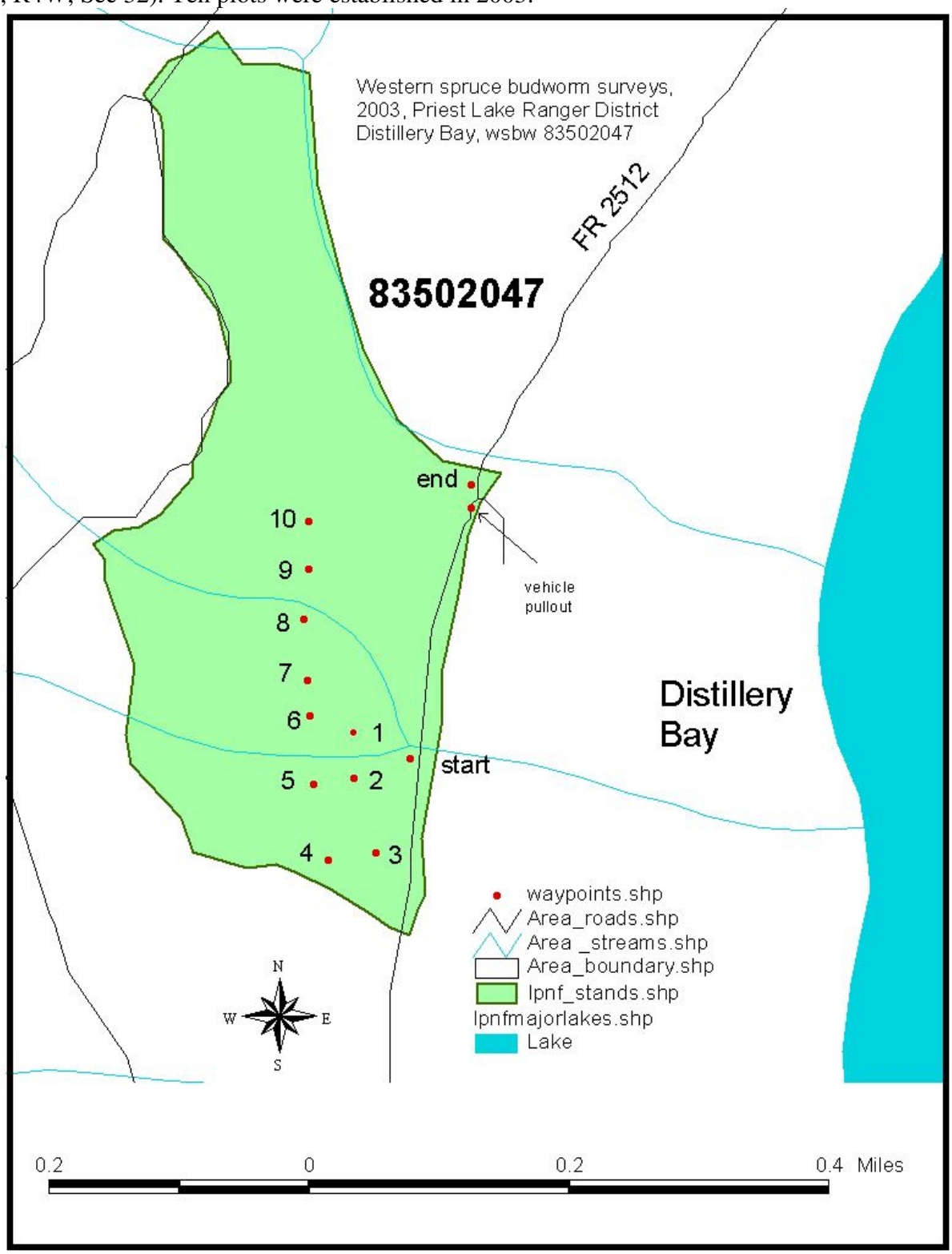
Area 2: Granite Creek western hemlock defoliation plots area on the Priest Lake Ranger District, IPNF (T62N, R5W, Sec 33 and 34; T61N, R5W, Sec 3). Ten plots were established in 2003.



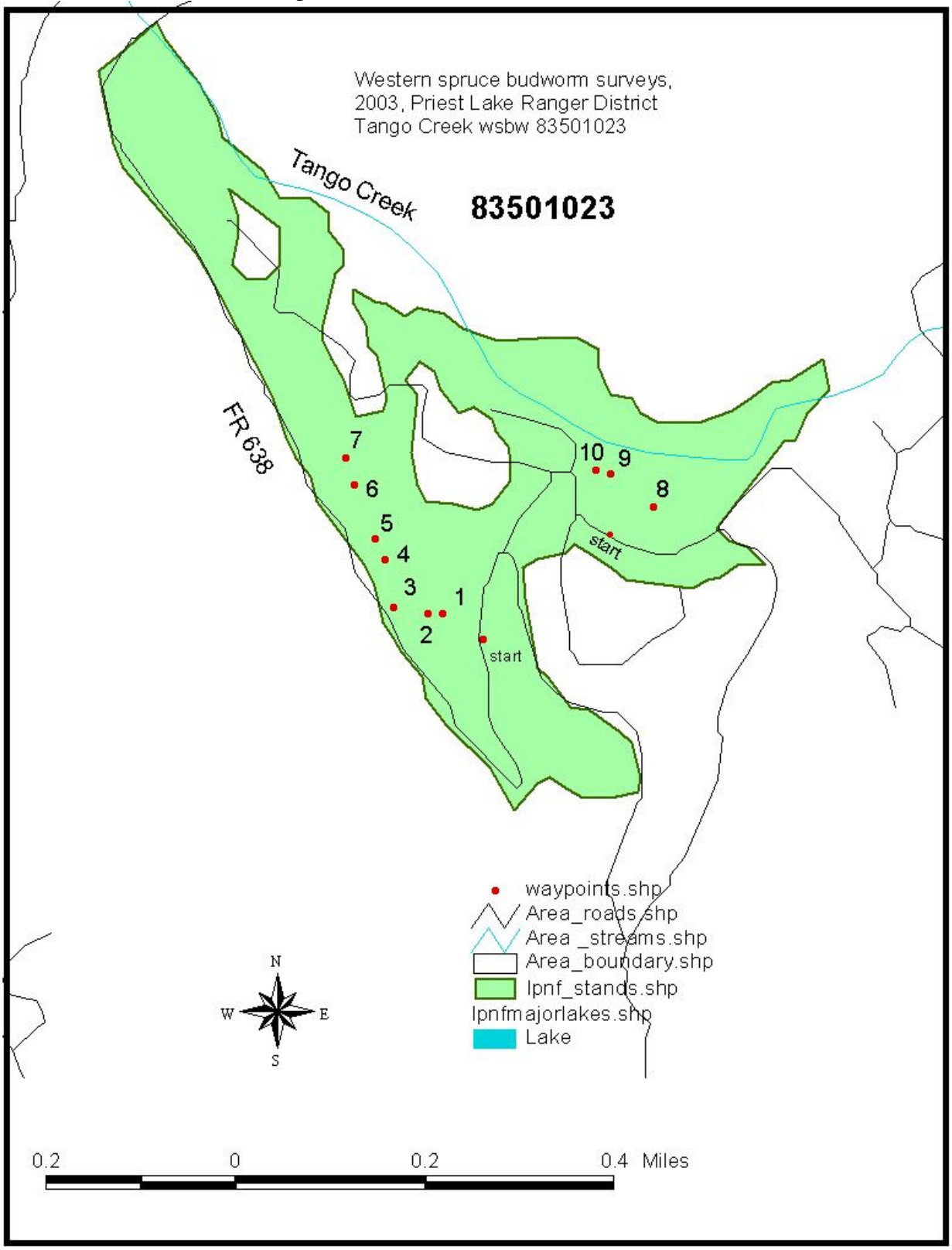
Area 3: Athol Creek western hemlock defoliation plots area on the Priest Lake Ranger District, IPNF (T62N, R5W, Sec 29 and 32). Ten plots were established in 2003.



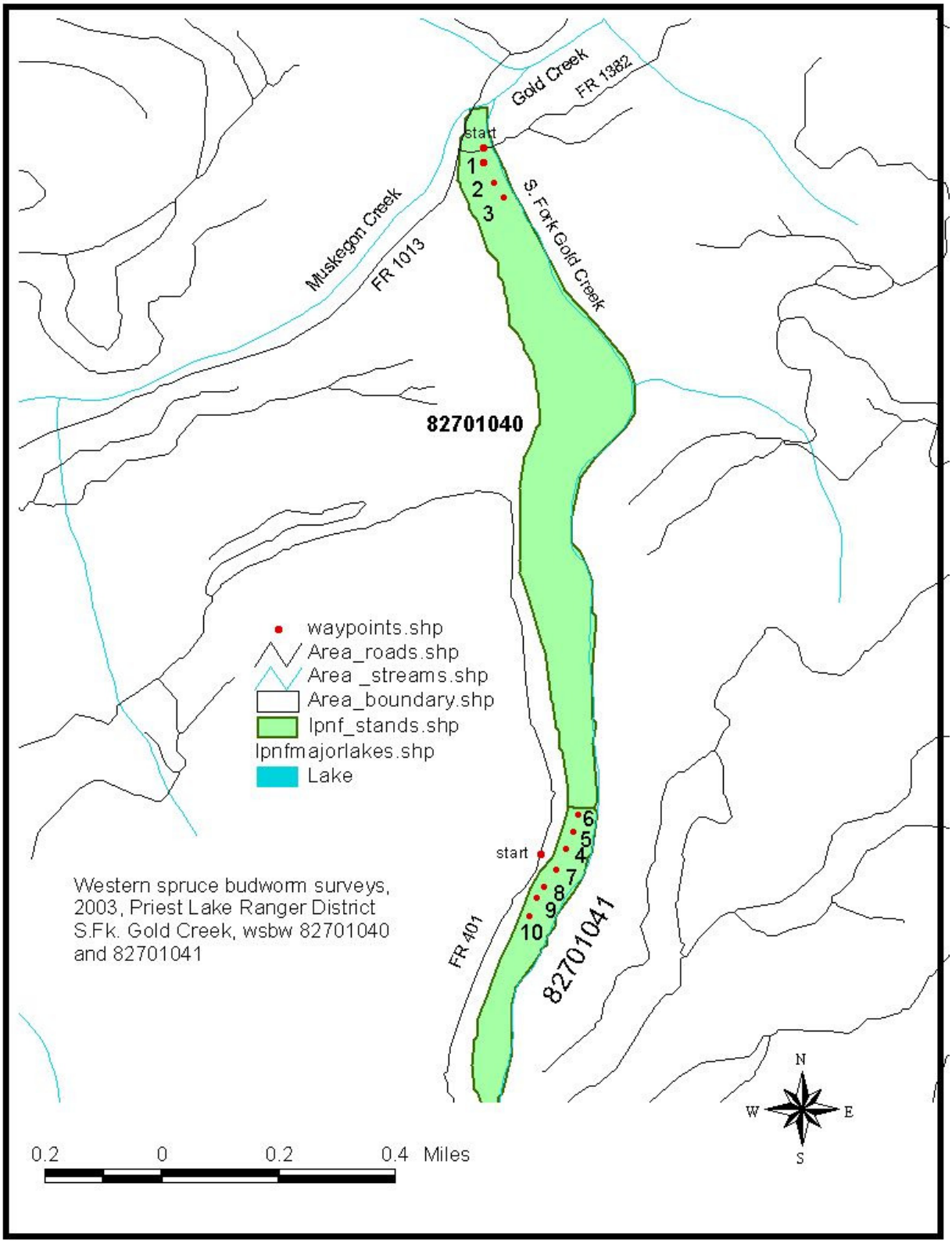
Area 4: Distillery Bay western hemlock defoliation plots area on the Priest Lake Ranger District, IPNF (T62N, R4W, Sec 32). Ten plots were established in 2003.



Area 5: Tango Creek western hemlock defoliation plots area on the Priest Lake Ranger District, IPNF (T62N, R4W, Sec 19 and 30). Ten plots were established in 2003.



Area 6: South Fork Gold Creek western hemlock defoliation plots area on the Priest Lake Ranger District, IPNF (T63N, R5W, Sec 20 and 29). Ten plots were established in 2003.



Appendix C: Results by Permanent Plot Area

Sandpoint Ranger District:
Porcupine Creek

The Porcupine Creek plot area (T29N, R2E, Sec 25 and T29N, R3E, Sec 30) is the only western hemlock defoliation permanent plot area located on the Sandpoint Ranger District, IPNF. It is also the only permanent plot area with defoliation data from 2002. Five of the 10 permanent plots were established in the fall of 2002 along Porcupine Creek, the remaining 5 were established in 2003. A total of 10 plots were measured in 2003-2006.

Stand Conditions:

Western hemlock was the dominant tree species in the overstory and regeneration plots in the Porcupine Creek permanent plots (Tables 1 and 2). Approximately 85% of the overstory trees pre acre (TPA) were western hemlock, with western redcedar (5% TPA), grand fir (5% TPA), white pine (3% TPA) and Douglas-fir (1% TPA) also present. The regeneration was also dominated by western hemlock seedlings/ saplings (85% TPA) with juniper (~6% TPA) and western redcedar (5% TPA) and minor numbers of subalpine fir, spruce, western white pine, and Douglas-fir seedling/ sapling trees per acre.

Table 1: Stand summary information for Porcupine Creek Defoliation Permanent Plots in 2003.

Species	Trees/ Acre	Basal Area	Quadratic Mean Diameter	% Stand Basal Area	% Stand Trees/ Acre
Grand Fir	22	10	9	6	5
White Pine	14	2	5	1	3
Douglas-Fir	4	2	9	1	1
Western Redcedar	21	8	9	5	5
Western hemlock	351	142	10	87	85
TOTAL	**411**	**164**	**9**	**100**	**100**

Table 2: Stand regeneration trees per acre summary information for Porcupine Creek Defoliation Permanent Plots in 2003.

Species	TPA 00 - 2.9 DBH	TPA 3.0 - 4.9 DBH	TOTAL
Subalpine Fir	30	0	30
Juniper	420	0	420
Spruce	60	0	60
Western White Pine	30	30	60
Douglas-fir	60	0	60
Western Redcedar	300	90	390
Western hemlock	5430	1080	6510
TOTAL	**6330**	**1200**	**7530**

Defoliation Summary:

Western hemlock was the most heavily defoliated species in the area. For defoliated plot trees, the top 1/3rd was more heavily defoliated than the middle and lower third (Table 3). In 2002 the top 1/3rd average defoliation rating was a 2.8, in 2003 a 4.7, in 2004 a 2.5, and in 2005 a 1.4. Defoliation peaked in 2003, and by 2006 defoliation was no longer observed in the plots.

Table 3: Defoliation rating summary by crown 1/3rd for trees in permanent plots along Porcupine Creek, Sandpoint Ranger District, Idaho Panhandle National Forest 2002-2005. No significant defoliation was observed in Porcupine Creek permanent plots in 2006

Species	# Trees**	Avg DBH	Min DBH	Max DBH	2002 Ratings*			2003 Ratings*			2004 Ratings*			2005 Ratings*		
					T[1]	M[2]	B[3]	T[1]	M[2]	B[3]	T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
SAF	1	2.8	2.8	2.8	1	1	1	3	2	2	1	1	1	1	1	1
DF	4	9.2	2.2	23.2	2	2	2	2.8	2.3	2	2.3	1.5	1.3	1.5	1.3	1
GF	6	8.2	2	11.2	1.7	2	2	2.3	2	2	1	1.2	1	1.5	1.2	1
S	2	2.55	2.4	2.7	1	1	1	2	2	1	1	1	1	1	1	1
WH	119	8.94	2	45.1	2.8	2.1	2	4.7	3.1	2	2.5	1.5	1.3	1.5	1.1	1.1

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100%

** In 2002 with only 5 plots tree numbers were as follow: SAF 1; DF 3; GF 3; S 2; WH 43

[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown

SAF = subalpine fir; DF= Douglas-fir; GF = grand fir; S = Engelmann spruce; WH = western hemlock

Average plot defoliation ratings were the highest in 2003 when the plot average top 1/3rd defoliation rating for western hemlock was 4.7, or between 51-75% defoliated. In that year 45 plot trees (44 western hemlock and 1 Douglas-fir) had a top 1/3rd defoliation rating of 6 (100%) and 37 trees (all western hemlocks) had a top 1/3rd defoliation rating of 5 (76-99%). By 2006 the average plot level defoliation rating had decreased to 1 (no visible defoliation).

In 2006, 59 of the 132 overstory plot trees exhibited some degree of top kill (1 Douglas-fir and 58 western hemlock). One overstory western hemlock was dead, but the crew could not determine if the death was caused by defoliation.

Defoliation on the regeneration plots was limited to western hemlock trees and was again highest in 2003, followed by 2002. No defoliation in the western hemlock regeneration was noted in 2004 and no additional defoliation ratings were taken on regeneration 2005-2007 (Table 4).

Table 4: Defoliation rating summary for regenerating trees in permanent plots along Porcupine Creek, Sandpoint Ranger District, Idaho Panhandle National Forest 2002-2004.

Species	# Trees **	2002 Ratings*			2003Ratings*			2004 Ratings*		
		T[1]	M[2]	B[3]	T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
WRC	3	1	1	1	1	1	1	1	1	1
PY	11	1	1	1	1	1	1	1	1	1
WH	7	1.5	1.5	1.5	3	2.4	2	1	1	1

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100%
** In 2002 with 5 plots tree numbers were as follow WRC 1; PY 1; WH 4
[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown
WRC = western redcedar; PY = Pacific yew; WH = western hemlock

Priest Lake Ranger District

Western hemlock is the dominant overstory species in all 5 permanent plot areas located on the Priest Lake Ranger District. Other species present include western redcedar, grand fir, Douglas fir, western larch, white pine, and subalpine fir. All plots in Priest Lake were established in 2003. Plot area average defoliation ratings for the top 1/3rd and whole tree generally increased or stayed the same from 2003-2004, then declined until no defoliation was noted in the plots in 2007.

Granite Creek

The Granite Creek Plots (T62N, R5W, Sec 33 and 34; T61N, R5W, Sec 3) were established in 2003 on the Priest Lake Ranger District, IPNF.

Stand Conditions:

The Granite Creek plot area is a western hemlock dominated forest with western hemlock comprising 89% of the TPA in the overstory and 77% of the regeneration TPA. The only other tree species present was western redcedar (Tables 5 and 6).

Table 5: Stand summary information for Granite Creek Defoliation Permanent Plots in 2003.

Species	Trees/ Acre	Basal Area	Quadratic Mean Diameter	% Stand Basal Area	% Stand Trees/ Acre
Western Redcedar	42	46	24	24	11
Western Hemlock	351	144	9	76	89
TOTAL	**393**	**190**	**10**	**100**	**100**

Table 6: Stand regeneration trees per acre summary information for Granite Creek Defoliation Permanent Plots in 2003.

Species	TPA 00 - 2.9 DBH	TPA 3.0 - 4.9 DBH	TOTAL
Western Redcedar	360	180	540
Western Hemlock	1080	750	1830
TOTAL	**1440**	**930**	**2370**

Defoliation Summary:

The no measurable defoliation was observed on redcedar for the overstory plot trees. Western hemlock defoliation ratings were higher in 2004 than in 2003, and in both years the top 1/3rd of western hemlock trees were more heavily defoliated than the bottom 2/3rds (Table 7).

Table 7: Defoliation rating summary for overstory trees in permanent plots along Granite Creek, Priest Lake Ranger District, Idaho Panhandle National Forest 2002-2005. No significant defoliation was observed in Granite Creek in 2006-2007.

Species	# Trees	Avg DBH	Min DBH	Max DBH	2003Ratings*			2004 Ratings*			2005 Ratings*		
					T[1]	M[2]	B[3]	T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
WH	117	10.09	2	38.1	2.6	1.9	1.4	3.3	2.7	2.2	2.3	2.0	1.9

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100% WH = western hemlock

[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown

In 2003, the average plot level defoliation rating was between 25 and 50% of current year's foliage missing, however there were individual trees with a top 1/3rd defoliation rating of 6 (100%). The average top 1/3rd defoliation rating for the plots were 2.6, or between 1-25% defoliated, but 5 plot trees had a top 1/3rd defoliation rating of 6, and 9 plot trees had a top 1/3rd defoliation rating of 5. Average plot defoliation ratings were the highest in 2004 when the plot average top 1/3rd defoliation rating for western hemlock was 3.3, or between 26-50% defoliated. In that year 20 plot trees had a top 1/3rd defoliation rating of 5 (76-99%). In 2005 average defoliation ratings per crown third began to decline and in 2006 little defoliation was observed in the plot area.

In 2007, 25 of 117 plot trees exhibited some degree of top kill (all western hemlock), and 8 mostly suppressed western hemlock had died. The crew was unable to determine if defoliation was the cause of death.

In 2003 minor defoliation was noted only on western hemlock seedling/ saplings. In 2004 minor defoliation was noted on redcedar regeneration; western hemlock regeneration defoliation was more intense than it had been in 2003 (Table 8). No additional defoliation ratings were taken on regeneration 2005-2007.

Table 8 : Defoliation rating summary for regeneration plot trees in permanent plots along Granite Creek, Priest Lake Ranger District, Idaho Panhandle National Forest 2002-2004.

Species	# Trees	2003Ratings*			2004 Ratings*		
		T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
WRC	7	1	1	1	1.3	1	1
WH	5	1.4	1	1	3.2	2.8	2.6

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100% WRC = western redcedar; WH = western hemlock

[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown

Athol Creek

The Athol Creek plots (T62N, R5W, Sec 29 and 32) were established in 2003 on the Priest Lake Ranger District, IPNF.

Stand Conditions:

The Athol Creek plot area is a western hemlock dominated forest with western hemlock comprising 98% of the TPA in the overstory and western redcedar (2% of the TPA) (Table 9). Ninety percent of the regeneration TPA are western hemlock with smaller components of western redcedar, Douglas-fir, and grand fir regeneration (Table 10).

Table 9: Stand summary information for overstory trees Athol Creek Defoliation Permanent Plots in 2003.

Species	Trees/ Acre	Basal Area	Quadratic Mean Diameter	% Stand Basal Area	% Stand Trees/ Acre
Western Redcedar	9	26	27	13	2
Western Hemlock	463	176	9	87	98
TOTAL	**472**	**202**	**10**	**100**	**100**

Table 10: Stand regeneration trees per acre summary information for Athol Creek Defoliation Permanent Plots in 2003.

Species	TPA 00 - 2.9 DBH	TPA 3.0 - 4.9 DBH	TOTAL
Grand Fir	60	0	60
Douglas- Fir	30	0	30
Western Redcedar	240	30	270
Western Hemlock	2160	750	2910
TOTAL	**2490**	**780**	**3270**

Defoliation Summary:

Defoliation was most significant in these plots in 2004, declining through 2005. In 2006 and 2007 no significant defoliation was noted. Western hemlock defoliation ratings were higher in 2004 than in 2003, and in both years the top 1/3rd of western hemlock trees were more heavily defoliated than the bottom 2/3rds (Table 11).

In 2007, 19 of 117 plot trees exhibited some degree of top kill (all western hemlock), and 4 more suppressed western hemlock had died. The crew was unable to determine if the mortality was the result of defoliation.

Table 11: Defoliation rating summary for overstory trees in permanent plots along Athol Creek, Priest Lake Ranger District, Idaho Panhandle National Forest 2002-2005. In 2006 top crown third defoliation was barely noticeable (average 1.08) and defoliation was notvisible in the lower crown thirds. In 2007 no defoliation was noted.

Species	# Trees	Avg DBH	Min DBH	Max DBH	2003Ratings*			2004Ratings*			2005 Ratings*		
					T[1]	M[2]	B[3]	T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
WH	117	10.09	2	38.1	2.6	1.9	1.4	3.3	2.7	2.2	2.3	2.1	2

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100% WH = western hemlock

[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown

In 2003 there was no defoliation noted in the regeneration in the Athol Creek Plots. In 2004, defoliation was noted on western hemlock, western redcedar, and grand fir regeneration; it was most intense (highest defoliation ratings) on grand fir regeneration (Table 12). Defoliation ratings were not taken on regeneration in this area 2005-2007.

Table 12: Defoliation rating summary for regeneration plot trees in permanent plots along Athol Creek, Priest Lake Ranger District, Idaho Panhandle National Forest 2003-2004.

Species	# Trees	2003Ratings*			2004 Ratings*		
		T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
WH	11	1	1	1	2	1.5	1.5
WRC	4	1	1	1	1.75	1.25	1.25
GF	1	1	1	1	3	2	2
DF	1	1	1	1	1	1	1

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100% WRC = western redcedar; WH = western hemlock; GF= grand fir; DF= Douglas-fir

[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown

Distillery Bay

The Distillery Bay plots (T62N, R4W, Sec 32) were established in 2003 on the Priest Lake Ranger District, IPNF. Western hemlock trees were more heavily defoliated than grand fir and Douglas-fir trees on the plots.

Stand Conditions:

The Distillery Bay plot area is a mixed conifer forest with western hemlock comprising 51% of the TPA in the overstory. Additional overstory species include slightly larger (QMD = 11) western redcedar (14% TPA), grand fir (12% TPA), birch (11% TPA) with occasional larch (6% TPA), western white pine (3%TPA) and Douglas-fir (3% TPA) (Table 13). Western hemlock and western redcedar dominated the regeneration, with grand fir, western white pine, birch, and larch also present (Table 14).

Table 13: Stand summary information for Distillery Bay Defoliation Permanent Plots in 2003.

Species	Trees/ Acre	Basal Area	Quadratic Mean Diameter	% Stand Basal Area	% Stand Trees/ Acre
Larch	51	20	8	7	6
Grand Fir	106	48	11	16	12
Western White Pine	23	14	15	5	3
Douglas-fir	30	10	8	3	3
Western Redcedar	119	50	11	17	14
Western Hemlock	441	138	8	46	51
Birch	93	20	6	7	11
TOTAL	**862**	**300**	**8**	**100**	**100**

Table 14: Stand regeneration trees per acre summary information for Distillery Bay Defoliation Permanent Plots in 2003.

Species	TPA 00 - 2.9 DBH	TPA 3.0 - 4.9 DBH	TOTAL
Larch	0	30	30
Grand Fir	150	150	300
Western White Pine	30	60	90
Western Redcedar	1680	390	2070
Western Hemlock	1410	1440	2850
Birch	0	90	90
TOTAL	**3270**	**2160**	**5430**

Defoliation Summary:

The average defoliation intensity increased in the overstory of this plot area from 2003 – 2004 and in both years the top 1/3rd of plot trees were more heavily defoliated than the bottom 2/3rds (Table 15). Individual tree defoliation ratings were lower on the Distillery Bay plots than in some others, with only 2 trees (1 western hemlock and 1 grand fir) receiving a top 1/3rd defoliation rating of 5 in 2003 (no 6 ratings) and in 2004 only one 6 and one 5 in the top 1/3rd of the crown (both western hemlocks). Defoliation was most intense in these plots in 2004, declining through 2005, and in 2006 and 2007 no significant defoliation was noted (Table 15).

In 2007, none of the 186 plot trees exhibited top kill, and 15 of the 186 plot trees were dead. The dead trees were grand fir (9) and western hemlock (6) and most (14) were suppressed or intermediate in crown position. The crew was unable to determine if the mortality was the result of defoliation.

No defoliation ratings were taken on regeneration after 2003.

Table 15: Defoliation rating summary for overstory trees in permanent plots along Distillery Bay, Priest Lake Ranger District, Idaho Panhandle National Forest 2002-2005. Average defoliation continued to decline through 2006 and in 2007 no visible defoliation was observed.

Species	# Trees	Avg DBH	Min DBH	Max DBH	2003Ratings*			2004Ratings*			2005 Ratings*		
					T[1]	M[2]	B[3]	T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
WH	148	6.5	2	16.9	2	1.6	1.3	2.5	2.1	2	2.0	1.8	1.7
GF	33	13.6	2.8	21.2	1.9	1.6	1.4	2.3	2.2	2.1	2.4	2.4	2.5
DF	5	8.44	5.7	11	1.6	1.4	1.2	1.8	2	2.2	1.4	1.4	1.8

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100% WH =western hemlock; GF =grand fir; DF =Douglas-fir

[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown

Tango Creek

The Tango Creek plots (T62N, R4W, Sec 19 and 30) were established in 2003 on the Priest Lake Ranger District, IPNF. Grand fir defoliation ratings were slightly higher than western hemlock defoliation ratings from 2003-2006. No visible defoliation was observed in 2007.

Stand Conditions:

The Tango Creek plot area is a western hemlock dominated forest (72% TPA) with western redcedar (21% TPA) and grand fir (6% TPA) (Table 16).

Table 16: Stand summary information for Tango Creek Defoliation Permanent Plots in 2003.

Species	Trees/ Acre	Basal Area	Quadratic Mean Diameter	% Stand Basal Area	% Stand Trees/ Acre
Grand Fir	9	4	9	4	6
Western Redcedar	34	20	12	18	21
Western Hemlock	114	86	16	78	72
TOTAL	**157**	**110**	**14**	**100**	**100**

Western redcedar and western hemlock dominate the regeneration; western white pine is also present (Table 17)

Table 17: Stand regeneration trees per acre summary information for Tango Creek Defoliation Permanent Plots in 2003.

Species	TPA 00 - 2.9 DBH	TPA 3.0 - 4.9 DBH	TOTAL
Western White Pine	60	0	60
Western Redcedar	1230	150	1380
Western Hemlock	1110	60	1170
TOTAL	**2400**	**210**	**2610**

Defoliation Summary:

Defoliation was most intense in these plots in 2004, declining through 2006, and in 2007 no significant defoliation was noted. Defoliation affected both overstory western hemlock and grand fir. Grand fir defoliation ratings were higher than western hemlock defoliation ratings 2003 -2006. Western hemlock defoliation ratings decreased slightly while grand fir defoliation ratings increased from 2003-2004. The top 1/3rd of both species tended to be more heavily defoliated than the lower 2/3rds (Table 18).

Table 18: Defoliation rating summary for overstory trees in permanent plots along Tango Creek, Priest Lake Ranger District, Idaho Panhandle National Forest 2002-2006. No significant defoliation was noted in these plots in 2007.

Species	# Trees	Avg DBH	Min DBH	Max DBH	2003 Ratings*			2004 Ratings*			2005 Ratings*			2006 Ratings*		
					T[1]	M[2]	B[3]	T[1]	M[2]	B[3]	T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
WH	51	16	2	45	4.8	4	3	4.3	3.7	3.6	2.3	1.9	1.8	1.2	1.1	1.1
GF	2	9	7.9	10.1	5	3.5	1.5	5	4	3.5	3	3	2	1.5	1.5	2

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100% WH = western hemlock; GF= grand fir

[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown

In 2007, 16 of 53 plot trees exhibited some degree of top kill (all western hemlock), and 2 of the 53 plot tees were dead (both suppressed western hemlock). The crew could not determine if the mortality was the result of defoliation.

The regeneration measured in the plot was composed of western hemlock, white pine, and redcedar; western hemlock was the most significantly defoliated (Table 19). No additional defoliation ratings were taken on regeneration 2005-2007.

Table 19: Defoliation rating summary for regeneration plot trees in permanent plots along Tango Creek, Priest Lake Ranger District, Idaho Panhandle National Forest 2003-2004.

Species	# Trees	2003Ratings*			2004 Ratings*		
		T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
WH	6	4	3.5	3.3	2.6	2.5	2.5
WP	1	2	1	1	1	1	1
WRC	9	1	1	1	1	1	1

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100% WRC = western redcedar; WH = western hemlock; WP= white pine

[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown

South Fork Gold Creek

The South Fork Gold Creek plots (T63N, R5W, Sec 20 and 29) were established in 2003 on the Priest Lake Ranger District, IPNF.

Stand Conditions:

The South Fork Gold Creek plot area is a western hemlock dominated forest (97% TPA) with an occasional subalpine fir (2% TPA) and western redcedar (1% TPA) (Table 20).

Table 20: Stand summary information for South Fork Gold Creek Defoliation Permanent Plots in 2003.

Species	Trees/ Acre	Basal Area	Quadratic Mean Diameter	% Stand Basal Area	% Stand Trees/ Acre
Subalpine Fir	7	2	7	1	2
Western Redcedar	4	14	24	8	1
Western Hemlock	357	156	10	91	97
TOTAL	**368**	**172**	**10**	**100**	**100**

Western hemlock dominates the regeneration; followed by western redcedar, subalpine fir, and spruce (Table 21).

Table 21: Stand regeneration trees per acre summary information for South Fork Gold Creek Defoliation Permanent Plots in 2003.

Species	TPA 00 - 2.9 DBH	TPA 3.0 - 4.9 DBH	TOTAL
Subalpine Fir	120	30	150
Spruce	30	30	60
Western Redcedar	300	0	300
Western Hemlock	1830	870	2700
TOTAL	**2280**	**930**	**3210**

Defoliation Summary:

Plot level average defoliation intensity ratings increased from 2003-2004. Subalpine fir defoliation ratings were slightly higher than western hemlock defoliation ratings in 2003 and 2006, but not 2004. The top 1/3rd of both species tended to be more heavily defoliated than the lower 2/3rds (Table 22). Defoliation was most intense in these plots in 2004, declining through 2005, and in 2006 and 2007 no significant defoliation was noted.

Table 22: Defoliation rating summary for overstory trees in permanent plots along the South Fork Gold Creek, Priest Lake Ranger District, Idaho Panhandle National Forest 2002-2005. No visible defoliation was noted on these plots in 2006 or 2007.

Species	# Trees	Avg DBH	Min DBH	Max DBH	2003Ratings*			2004Ratings*			2005Ratings*		
					T[1]	M[2]	B[3]	T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
WH	126	10.2	2	47.4	3.2	2.3	1.8	4	3.4	3.1	1.8	1.7	1.5
SAF	3	4.4	2.3	7.2	3.3	2.7	1.3	3.3	2.7	2.7	1.8	2	2
ES	1	3.1	3.1	3.1	1	1	1	1	1	1	1	1	1

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100% WH = western hemlock; SAF= subalpine fir; ES= Engelmann spruce
[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown

In 2007, 39 of 130 plot trees exhibited some degree of top kill (all western hemlock), and six of 130 plot trees were dead (all western hemlock). The crew was unable to determine if mortality was a result of defoliation.

In 2003 western hemlock was the only regeneration species to have measurable defoliation, in 2004 regenerating Engelmann spruce and subalpine fir had higher defoliation intensity ratings than western hemlock (Table 23). No additional defoliation ratings were taken on regeneration 2005-2007.

Table 23: Defoliation rating summary for regeneration plot trees in permanent plots along South Fork Gold Creek, Priest Lake Ranger District, Idaho Panhandle National Forest 2003-2004.

Species	# Trees	2003Ratings*			2004 Ratings*		
		T[1]	M[2]	B[3]	T[1]	M[2]	B[3]
WH	11	1.45	1.36	1.2	3	3	2.9
SAF	1	1	1	1	5	5	5
WRC	2	1	1	1	1	1	1
ES	1	1	1	1	5	5	5

* Defoliation Ratings based upon Twardus (1985): 1= 0%, 2= 1-25%, 3= 26-50%, 4= 51-75%, 5=76-99%, 6= 100% WRC = western redcedar; WH = western hemlock; SAF= subalpine fir, ES= Engelmann spruce
[1]T = Top 1/3rd of crown [2]M= Middle 1/3rd of crown [3]B= Bottom 1/3rd of crown